LARVAL HABITATS OF SOME VIRGINIA *CULICOIDES* (DIPTERA: CERATOPOGONIDAE) [1]

JAKIE ALEXANDER HAIR, E. C. TURNER, JR.,[2] AND D. H. MESSERSMITH [3]
Department of Entomology, Virginia Polytechnic Institute, Blacksburg

Most aspects of the biology of *Culicoides* (Diptera: Ceratopogonidae) have been neglected in the past. However, the ability of these biting midges to transmit human and animal pathogens is receiving increasing attention. Our knowledge of *Culicoides* breeding sites has increased greatly in recent years but as Williams (1964) pointed out, the larval habitats of the majority of the world species of *Culicoides* are unknown. He also mentioned that for those that are known, the habitats are varied and frequently only a single habitat is known for a given species. Table 1 presents a literature summary of the breeding habitats for species pertinent to this study.

The present survey was undertaken to obtain a more complete knowledge of the larval habitats of the Virginia *Culicoides*.

METHODS AND MATERIALS. Several methods were used in determining the breeding sites. Emergence traps similar to those described by Dove *et al.* (1932) were used to a very limited degree, but the following method proved to be more satisfactory.

During the summers of 1964 and 1965 many likely breeding sites of *Culicoides* were visited. Several 2-quart samples of mud, leaf debris and similar solid materials were placed in cardboard 1-gallon food containers coated with paraffin. When probable sites such as tree-holes and stump-holes were sampled, attempts were made to remove the entire contents of the tree or stump-hole. Pond edges were sampled by scooping up mud and soil for a few inches along both sides of the water line. These samples were retained in gallon food cartons in the same manner as mentioned above for solid materials. In the laboratory the solid tops were replaced with screen tops of 40 mesh saran screen. A small stoppered hole in the center of the screened top permitted easy removal of adults after emergence. All samples were held at 75° F±3 in a well lighted room. Distilled water was used when needed to moisten solid samples to prevent drying out before adult emergence was complete. Adults were removed at least once daily and killed in 70 percent ethanol.

DESCRIPTION OF BREEDING SITES AND CULICOID FAUNA PRESENT

TREE AND STUMP-HOLES. In this environment two distinct sets of conditions exist which will influence the species of *Culicoides* present. Wet tree or stump-holes are defined as cavities which retain water even in periods of dry weather. Stumps of white oak, *Quercus alba* L., were common and supported large numbers of one or two species. Dry tree-holes were generally more protected from rain and evaporation, and excessive rainfall drained off. The dry tree-holes most productive in our study had a small opening leading into a large hollow containing moist decaying organic matter.

C. arboricola Root and Hoffman. In this survey *arboricola* was found in both wet and dry tree-holes. At least two records were made of its presence in wet white oak stumps where it appeared in small numbers with *guttipennis* (Coquillett). These stumps were located in Montgomery and Rockingham counties and contained decaying leaves, other organic

[1] Supported by the National Institutes of Health as project No. AI–05947.

[2] Graduate Research Assistant and Professor of Entomology, respectively. Department of Entomology, Virginia Polytechnic Institute, Blacksburg.

[3] Associate Professor, Present address: Department of Entomology, University of Maryland, College Park.

TABLE 1.—A literature review of the breeding sites of *Culicoides* pertinent to this survey.

Species	Habitats	References
arboricola	Wet tree-holes, wet wood debris, water and moist woody debris.	Jones (1961), Root and Hoffman (1937), Wirth and Bottimer (1956), Snow, *et al.* (1957).
biguttatus	Decaying leafmuck, reservoir margins and leafy pools, sulfate waste basin, flooded wooded bottom, rain pool on mud flat, vegetated stream margin.	Williams (1955), Snow *et al.* (1957), Murray (1957), Wirth (1951).
crepuscularis	*Carex* peat and organic mud, mud, sand at pond margins, water tank overflows, septic tank effluent.	Williams (1955), Wirth and Bottimer (1956), Jones (1961), Snow *et al.* (1957).
footei	Oak and maple tree-holes, tree-hole debris.	Wirth and Jones (1956).
furens	Salt marshes, bays, drainage ditches, wetted areas subject to flooding.	Wall and Doane (1960), Bidlingmayer (1957), Woke (1954), Williams (1964), Goulding *et al.* (1953).
guttipennis	Tree holes, crotches, stumps.	Jones (1961), Murray (1957), Root and Hoffman (1937), Messersmith (1961) and others.
haematopotus	Spring seepage areas, margins of streams, rivers, and lakes, alkaline streams, overflow areas at watering trough, mud flat, woody debris, muddy sandbar, sandy stream margin.	Jones (1961), Murray (1957), Snow *et al.* (1957), Jamnback (1965), Wirth (1951).
hinmani	Moist debris in tree-holes.	Snow *et al.* (1957), Wirth and Bottimer (1956), Wirth and Jones (1956).
hollensis	Salt marshes, drainage ditches, bays, all with vegetative cover.	Jamnback (1965), Jamnback *et al.* (1958), Wall and Doane (1965).
melleus	intertidal sand.	Goulding, *et al.* (1953), Wall and Doane (1960), Jamnback *et al.* (1958).
nanus	Tree-holes.	Snow, *et al.* (1957), Jones (1961), Wirth and Bottimer (1956), Root and Hoffman (1937), Messersmith (1961).
obsoletus	Clean straw beside a chicken house, spruce needles, twigs and wood chips.	Jamnback and Wirth (1963).
piliferus	Osmunda fernbog, stream edge, mud with grass, soft mud, sand and silt mixture.	Wirth and Hubert (1962), Jamnback (1965).
sanguisuga	Moist leaves on well drained sites, straw near chicken house, spruce needles, twigs and wood chips.	Jamnback and Wirth (1963).
snowi	Debris in tree-holes.	Wirth and Jones (1956).
spinosus	Grassed boggy streams, mud bars, pond margins, flooded wooded bottom, mud flat.	Jones (1961), Wirth and Bottimer (1956), Snow, *et al.* (1957).

TABLE 1.—*Cont.*

Species	Habitats	References
stellifer	Mud and wet soil with decaying leaves and roots, grassy margin of lake, mud flat, decaying leaves at stream edge, mud at pond margins.	Williams (1955), Snow, *et al.* (1957), Murray (1957), Wirth and Bottimer (1956), Jones (1961).
travisi	Wet grass and mud from marsh of meadow, cattail swamp, leaves and detritus from stream margin, mud bars, leafy pools in wooded area.	Jamnback (1965), Jones (1961), Snow *et al.* (1957).
variipennis	manure-contaminated areas around livestock watering tanks.	Wirth and Jones (1957).
venustus	Stream margins, mud, or mud with grass roots where depressed by cattle hoofs, Sphagnum moss.	Jamnback (1965), Jones (1961), Snow *et al.* (1957).
villosipennis	Wet tree-holes.	Jamnback (1965), Jones (1961), Root and Hoffman (1937), Snow, *et al.* (1957).

material and some soil which was covered with dark brown water. Larger numbers of *arboricola* larvae were found in a drier habitat in a hollow buckeye tree (*Aesculus octandra* March) near Newport, Va. (Giles Co.) (See figure 1). A small, slit-like cavity facing north opened into a 3–4 gallon hollow which was filled with peat-like organic matter. The non-compacted substrate contained only enough water to make it moist. A number of earthworms, slugs, and other dipterous larvae were present which probably kept the substrate well aerated. Three other species, *hinmani, stellifer* and *footei,* were found breeding in conjunction with *arboricola* in this case.

C. footei Wirth and Jones. This species was taken in rather large numbers on May 28, 1965, from the same buckeye tree cavity mentioned under the heading *arboricola.* According to Wirth (1965) this was the first report of this species having been taken since its original description in 1956. Future collections from the site yielded mostly *guttipennis* since the habitat changed from a dry to wet habitat upon removal of the organic debris.

C. guttipennis (Coquillett). This was found to be the most abundant tree and stump-hole breeder in Virginia. This can possibly be explained by its ability to survive under a wide range of environmental conditions. Temperature, pH, and dissolved o_2 readings indicated the ability of this species to survive under the following conditions: temperature range 2.7 –30.4° C; pH 5.0 –8.2: and dissolved o_2 7.0—10 p.p.m. *C. guttipennis* was found abundantly in both wet and dry tree and stump-holes and comprised over 95 percent of all culicoid fauna collected from wet tree and stump holes. Mature larvae were found and removed from a white oak stump in Blacksburg on April 27, May 18, June 5 and 29, August 8, September 1 and 20. Larvae were not present in this stump in July. Otherwise, there was almost continuous breeding of this species during the summer months of 1965 in southwestern Virginia. Breeding sites in trees and stumps were so extensive and varied that they will not be described further.

C. hinmani Khalaf. This species apparently prefers dry tree-holes for oviposition and is relatively scarce as indicated by light trap surveys made during 1959-60 (Messersmith 1961, 1965). However, collections on live animal hosts used during 1965 in another study (Hair, 1965) have shown this species to be somewhat more

FIG. 1.—Hollow buckeye tree which supported larval populations of *Culicoides arboricola, C. footei, C. hinmani* and *C. stellifer.*

prevalent than previously indicated by the above author. Only one breeding site, the same as described for *footei,* was found for this species during the summers of 1964 and 1965. About 100 male and female specimens were collected from the buckeye tree.

C. nanus Root and Hoffman. Small numbers of this species have been collected in Rockingham County from two white oak stumps containing water and an accumulation of organic debris. Messersmith (1961) also reared a few specimens from stump water collections which might indicate that this species prefers a wet larval habitat somewhat similar to *guttipennis. C. guttipennis* larvae were abundant in both of the *nanus* collections.

C. stellifer (Coquillett). Specimens were collected from the same hollow buckeye tree habitat described for *footei* and *hinmani.* About 25 specimens were collected from the site.

C. sanguisuga (Coquillett). A single speciman of this species was collected from a wet white oak stump in Rockingham County near Ottobine, Virginia on April 24, 1964. As Table 1 indicates, this was an unusual habitat and probably accounted for the presence of only a single specimen.

C. snowi Wirth and Jones. This tree-hole breeder was encountered only once in this survey. A single specimen emerged from water and debris taken from a white oak stump in Rockingham County on April 24, 1964. *Guttipennis* was found in large numbers in the same stump.

C. villosipennis Root and Hoffman. This species is evidently a wet stump and tree-hole breeder. Second to *guttipennis,* it was the most abundant species recovered from wet stumps and tree-holes. It was reared in moderate numbers from stump water taken near Wytheville (Wythe Co.), Ottobine (Rockingham Co.) and New Castle, Va., (Craig Co.) All stumps were white oak and characterized by having organic debris covered by at least several inches of water. In all instances *guttipennis* was also present.

SALINE HABITATS. In addition to the coastal region of Virginia which supports at least three species of *Culicoides,* the brine pools near Saltville, Va. provided an inland saline habitat in which a fourth species was found.

C. variipennis australis Wirth and Jones. The presence of this species at Saltville was reported by Snow, *et al.* (1957) and Messersmith (1961). In accordance with the findings of these workers, the areas of greatest larval concentration were algal mats (*Lyngbya* and *Anacystis* spp.) in moist depressions and drainage ditches. During June 1964, larvae were so numerous in these algal mats that the entire surface of the algae glistened in the sun due to larval movement. Thousands emerged from half-gallon samples of mud and algae. An Olin Matheson Company foreman of the area stated that frequently the brine of the saline pools in the *Culicoides* breeding area contained concentrations of salts above 250 parts/mille. Most areas were

exposed to direct sunlight. This subspecies was not found along the coast.

C. hollensis (Melander and Brues). Even though extensive surveys of the Virginia Beach, Va., area were made, sites of heavy *hollensis* breeding were not located. Small numbers of this species emerged from several mud and sand samples taken near Rudee Inlet. The most productive breeding area found was a seepage or drainage ditch partially shaded by a sparse growth of *Spartina alterniflora* (See Figure 2). A thin layer of mud covering compacted sand apparently served as the larval substrate.

C. furens (Poey). A number of larval habitats were located for this species at Virginia Beach. The site of greatest larval abundance, however, was essentially the same as that described for *hollenis,* the chief differences being that *furens* was found nearer the mouth of the ditch where sand and an accumulation of organic debris provided the larval substrate. There was little or no mud present and the area was possibly moistened, but not generally flooded, during high tide. *Spartina alterniflora* provided sparse cover and served to hold the accumulation of decaying organic debris.

C. melleus (Coquillett). Adults of this species were by far the most abundant species at Virginia Beach during the summers of 1964 and 1965. However, heavy concentrations of larvae were not found. Fifteen to 20 two-quart intertidal sand samples all yielded extremely small numbers of emerging adults. Most of these were females.

FIG. 2.—A salt marsh breeding site of *Culicoides hollensis* and *C. furens.*

MOIST TERRESTIAL HABITATS. MOSTLY ALKALINE, DUNG-POLLUTED, AND GENERALLY EXPOSED TO DIRECT SUNLIGHT. Southwestern Virginia is a large cattle-producing area and many overflowing watering troughs or small polluted streams in cow pastures provide excellent breeding sites for several species of *Culicoides.* Extreme

pollution of an area seemed to limit the culicoid population to one, or possibly two species, whereas slight pollution seemed to provide a suitable habitat for several additional species.

Crepuscularis Malloch. This species was extremely abundant during the summer of 1964 and somewhat less in 1965. During 1964 several highly polluted watering areas provided sites for extensive larval breeding. An overflowing watering trough at Chilhowie, Va. (Smyth County) provided a larval breeding area 20–30 feet in diameter (See figure 3). Mud, 2 feet deep in some areas, was covered with shallow pools of water. Light silt around the edges of these puddles produced the greatest numbers of larvae. The area was exposed to direct sunlight and was frequented by about 100 dairy cows. Massive numbers of *variipennis variipennis* were also present, as well as a few *stellifer*.

Another area of heavy breeding was a small watering pond near Blacksburg of approximately one-half acre in size which supplied water for about 150 dairy and beef cattle. Loose mud several feet wide and a foot or more deep bordered the small pond and was heavily polluted with cattle feces and urine. Mud and water from the area had an average pH of 9.5. *C. variipennis variipennis* were present in even greater numbers than *C. crepuscularis*.

A small, shallow, rocky stream flowing through a hog lot near Blacksburg provided an interesting breeding site for moderate numbers of *crepuscularis* and lesser numbers of *haematopotus, variipennis variipennis* and *venustus* (see figure 4). The stream passed through a series of minute islands and pockets produced by frequenting hogs. Hog dung was very abundant and water from the still pockets had a pH of 9.2. The entire area was exposed to direct sunlight.

Numerous other animal watering areas supported small numbers of *crepuscularis* and all sites at which this species was

FIG. 3.—Larval breeding site of *Culicoides variipennis variipennis, C. crepuscularis* and *C. stellifer*.

found contained at least moderate pollution.

C. haematopotus Malloch. Polluted sites as described for *crepuscularis* are probably not the most important breeding sites for *haematopotus* in Virginia, but since *haematopotus* was encountered several times at this type of habitat, it seemed necessary to comment on this kind of environment as a secondary breeding site. In addition to the hog lot site mentioned under *crepuscularis* where *haematopotus* was found in very small numbers, two or three other very similar but less polluted habitats produced small numbers of *haematopotus, crepuscularis* and *v. variipennis.*

C. obsoletus (Meigen). A pile of used chicken litter provided the only breeding site found for this species (see figure 5). The litter contained about 60–75 percent wood shavings and the balance was chicken feces and feathers. The litter pile was located in an open field and received direct sunlight. The outer 2–3 in. of the pile was extremely dry and covered the slightly moist, decaying litter beneath. Most larvae were located at the moist-dry interface. Larvae were present in mid-August.

C. stellifer (Coquillett). This species was reared from heavily polluted mud and water collected from an overflowing watering trough described under *crepuscularis* in this section.

C. variipennis variipennis (Coquillett). This is an extremely abundant species in southwestern Virginia and several of the most productive habitats have been mentioned under the *crepuscularis* heading of this section. Almost all areas having moisture and pollution from animal feces supported at least light *v. varripennis* breeding for most of the summer of 1964 and to a lesser degree in 1965. Habitats in central and southwestern Virginia were

FIG. 4.—Polluted hog-lot stream which supported *Culicoides crepuscularis, C. variipennis variipennis, C. haematopotus* and *C. venustus.*

so numerous that it is impractical to mention all of them here. Most sites were alkaline. Northern and eastern sections of the state were not surveyed for this species.

C. venustus Hoffman. The only breeding site located for this species was the stream polluted by hog feces mentioned under the *crepuscularis* heading in this section.

GENERALLY ACIDIC, SOIL AND PLANT HABITATS OTHER THAN TREE-HOLES. This heading is intended to cover a very broad range of habitats not listed under one of the other three habitat headings.

C. biguttatus (Coquillett). A light population of *bigattatus* larvae were found to occupy the same habitat as *stellifer, piliferous, spinosus* and *haematopotus* near Vesuvius, Virginia on a tributary of Big Mary's Creek. Areas of soft black mud partially covered with decaying leaves and bordering a small, swift flowing steam provided the larval substratum. The mud ranged up to 6 in. deep, was several feet wide in some areas and had a pH of 6.6. Larvae also appeared on an occasional sandbar located within or near the edge of the stream. The area was heavily shaded but had very little undergrowth. Larvae were present from early July to September.

Two other habitats from Vesuvius included wet leaves from a shaded pool beside a small mountain stream and mud and decaying organic matter from the edge of the stream. In all cases *biguttatus* seemed to prefer extremely moist and shaded sites. The earliest larval collection was on June 18 and the latest on September 2, 1964.

C. guttipennis (Coquillett). *C. guttipennis* breeds almost exclusively in wet tree or stump-holes but one specimen emerged from wet leaves taken from a wildlife watering pond at the Broad Run Game Reserve in Craig Co. on July 12, 1964. A steep slope on one side of the pond accounted for an accumulation of leaves in that side of the small pond which had a pH of 6.7. The accumulation of leaves was several feet deep and partially submerged (See figure 6). The area was shaded from afternoon sun by overhead vegetation.

C. haematopotus Malloch. Several breeding sites for this species were located in this survey. Moderate numbers of larvae and pupae were removed from the wildlife watering pond in Broad Run Game Reserve mentioned under *guttipennis* above. Larvae were present from early June until late July.

A sandy area on the bank of Big Mary's Creek between Mine and McLung Mountains in Rockbridge County also produced several *haematopotus* larvae and pupae. Mud and leaves from the edge of a tributary of Big Mary's Creek was a heavy breeding site for this species and supported small numbers of *piliferus, spinosus,* and *stellifer.*

The most extensive breeding area of *haematopotus* was located between Mine and McLung Mountains on Big Mary's Creek and has been described under the *biguttatus* heading of this section.

Mud from the edge of a half-acre wildlife watering pond in Broad Run Game Reserve was found to support small numbers of *haematopotus.* There was little organic matter present and the larvae were found most abundantly near the water's edge.

C. piliferus Root and Hoffman. One *piliferus* larval habitat of soft black mud and decaying leaves has been listed under *biguttatus* in this section and mud and leaves from a creek's edge provided a second and is described under *haematopotus.* Small numbers of larvae were present at both sites.

C. sanguisuga (Coquillett). The site at Broad Run Game Reserve in Craig Co. which was described for *guttipennis* supported small numbers of this species in mid-June 1964. In Rockbridge Co., heavy breeding was encountered in mid-August of 1964 in a large pile of decaying leaves on the steep side of a road embankment between Mine and McLung Mountains. The outer few inches of the leaves in the pile were very dry and covered only slightly moistened leaves. *Sanguisuga* larvae could be seen migrating between

FIG. 5.—A pile of used chicken litter which provided a breeding site for *Culicoides obsoletus.*

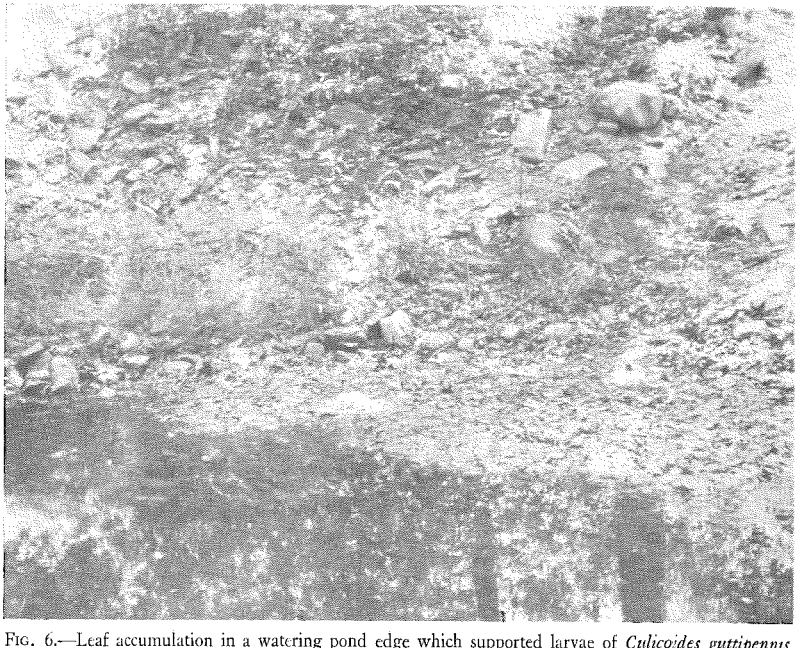

FIG. 6.—Leaf accumulation in a watering pond edge which supported larvae of *Culicoides guttipennis, C. haematopotus, C. sanguisuga and C. stellifer.*

the leaves when compacted leaf packets were separated.

C. spinosus Root and Hoffman. Moderate numbers of this species were recovered from the site of soft black mud with decaying leaves mentioned under *biguttatus* and the mud and leaf habitat referred to under *haematopotus*. Wet leaves from the side of a small intermittent stream at Broad Run Game Reserve in Craig Co. supported small numbers of *spinosus*. In all cases, breeding sites were found in well shaded areas.

C. stellifer (Coquillett). *C. stellifer* was found breeding at several sites which have already been mentioned. The site which has been given for *guttipennis* in this section supported small numbers of larvae. Moderate numbers of *stellifer* larvae were found in the *biguttatus* and *haematopotus* habitats described above.

C. travisi Vargas. Only one breeding site of this species was found. Small numbers of *travisi* were taken from wet leaves near the edge of a small stream at Broad Run Game Reserve in Craig Co. The leaf accumulations had small amounts of mud and sand intermixed and were well shaded by overgrowth vegetation.

Literature Cited

BIDLINGMAYER, W. 1957. Studies on *Culicoides furens* at Vero Beach. Mosq. News 17:292–94.

DOVE, W. E., HALL, D. G., and HULL, J. B. 1932. The salt-marsh sandfly problem. Ann. Entomol. Soc. Amer. 25:505–22.

FOOTE, R. H., and PRATT, H. D. 1954. The *Culicoides* of the eastern United States (Diptera, Heleidae). Public Health Monog. 18:1–53.

GOULDING, R. L., CURRAN, R. E., and G. C. LABRECQUE. 1953. Insecticides for control of sandflies in Florida. J. Econ. Entomol. 46:37–43.

HAIR, J. A. 1965. Unpublished data.

JAMNBACK, H. 1965. The *Culicoides* of New York State (Diptera: Ceratopogonidae). N.Y.S. Mus. and Sci. Serv. Bull. 399, 154 p.

JAMNBACK, H., WALL, W., and COLLINS, D. L. 1958. Control of *Culicoides melleus* (Coq.) (Diptera: Heleidae) in small plots, with brief descriptions of the larvae and pupae of two coastal *Culicoides*. Mosq. News 18:64–70.

JAMNBACK, H., and WIRTH, W. W. 1963. The species of *Culicoides* related to *obsoletus* in Eastern North America (Diptera: Ceratopogonidae) Ann. Entomol. Soc. Amer. 56:185–98.

JONES, R. H. 1961. Observations on the larval habitats of some North American species of *Culicoides* (Diptera: Ceratopogonidae). Ann. Entomol. Soc. Amer. 54:702–10.

MESSERSMITH, D. H. 1961. Studies on *Culicoides* (Diptera: Ceratopogonidae) and their relationship to infectious synovitis in poultry in Virginia. Virginia Polytechnic Institute. Ph.D. Dissert., 125 p., Blacksburg, Va.

MESSERSMITH, D. H. 1965. *Culicoides* (Diptera: Ceratopogonidae) associated with poultry in Virginia. Mosq. News 25:321–24.

MURRAY, W. S. 1957. Investigations on the bionomics of *Culicoides obsoletus* (Meigen) and other biting midges at Mount Solon, Virginia. Mosq. News 17:77–82.

ROOT, F. M., and HOFFMAN, W. A. 1937. The North American species of *Culicoides*. Amer. J. Hyg. 25:150–76.

SNOW, W. E., PICKARD, E., and MOORE, J. B. 1957. The Heleidae of the Tennessee River Basin. J. Tenn. Acad. Sci. 32:18–36.

WALL, W. J., and DOANE, O. W. 1960. A preliminary study of the blood sucking Diptera on Cape Cod, Massachusetts. Mosq. News 20: 39–44.

WILLIAMS, R. W. 1955. Observations on the bionomics of some *Culicoides* of Cheboygan County, Michigan (Diptera: Heleidae). Bull. Brooklyn Entomol. Soc. 50:113–20.

WILLIAMS, R. W. 1955. Studies on the *Culicoides* of Baker County, Georgia (Diptera: Heleidae). I. Preliminary survey and observations. Ann. Entomol. Soc. Amer. 48:30–34.

WILLIAMS, R. W. 1964. Observations on habitats of *Culicoides* larvae in Trinidad, W. I. (Diptera: Ceratopogonidae). Ann. Entomol. Soc. Amer. 57:462–66.

WIRTH, W. W. 1951. New species and records of Virginia Heleidae (Diptera). Entomol. Soc. Wash. Proc. 53:313–326.

WIRTH, W. W. 1965. Personal Communication.

WIRTH, W. W., and BOTTIMER, L. J. 1956. A population study of the *Culicoides* midges of the Edwards Plateau region of Texas. Mosq. News 16:256–66.

WIRTH, W. W., and HUBERT, A. A. 1962. The species of *Culicoides* related to *piliferus* Root and Hoffman in Eastern North America (Diptera: Ceratopogonidae). Ann. Entomol. Soc. Amer. 55:182–95.

WIRTH, W. W., and JONES, R. H. 1956. Three new North American species of tree-hole *Culicoides* (Diptera: Heleidae). Entomol. Soc. Wash. 58:161–68.

WIRTH, W. W., and JONES, R. H. 1957. The North American subspecies of *Culicoides variipennis* (Diptera: Heleidae). U.S.D.A. Tech. Bull. 1170, 35 p.

WOKE, P. A. 1954. Observations on Central American biting midges (Diptera: Heleidae). Ann. Entomol. Soc. Amer. 47:61–74.